over these areas varies from a mere veneer to at least 2 feet. Along the outer vertical face of the reef on the opposite (north) side of this same cove many barren areas were found to be covered with a surface layer of spicule rock from 1 to 12 inches in thickness. This layer extends back into many subterranean caverns in the reef for a distance of several feet, and when added to the area of the reef face now covered with living alcyonaria constitutes an almost complete covering of spicule rock over the entire reef face for more than one-third of a mile from the head of the cove.

While these observations have made it clear that on certain of the pacific reefs the alcyonaria are important coral forming agents their relative importance can be determined only after borings have been made through some reefs to determine whether or not the present conditions are transient or have been maintained over long periods during the upbuilding of the reefs.

OBSERVATIONS UPON THE ALKALINITY OF THE SURFACE WATER OF THE TROPICAL PACIFIC

By Alfred Goldsborough Mayer

DEPARTMENT OF MARINE BIOLOGY, CARNEGIE INSTITUTION OF WASHINGTON

Communicated, June 22, 1917

On a voyage from San Francisco, California, to Honolulu and thence to Pago Pago, Samoa; and also upon the return over the same route, we made daily observations of the hydrogen-ion concentration of the surface water, using for this purpose a set of thymolsulphonephthalein tubes standardized and prepared by Prof. J. F. McClendon, and kindly presented to us for this purpose.

It was found that in the mid-Pacific, N.N.E. of Samoa, the surface water at or near the equator was cooler, and less alkaline than 5°–10° north or south of this region. This fact will appear upon inspection of the tables at the end of this paper. It seems that the water of the equator at 24°.9 C. is so low in alkalinity as to be comparable in this respect with the water of only 15°C. about 300 miles off the mouth of San Francisco Harbor, California.

The low alkalinity of the water near the equator was usually although not invariably associated with a decided easterly set opposite in direction to the prevailing westerly surface drift of the tropical Pacific.

This suggests that counter currents at the surface in the tropical Pacific may be regions wherein the cold bottom water is rising to the surface; and that this cold water has not yet had time to come into

equilibrium with the carbon dioxide of the atmosphere, and thus still retains some of the relative acidity associated with its former low temperature.

Similarly, we would expect cold currents drifting into warmer regions to retain their relative acidity to a greater degree than is warranted by their augmenting temperature; and this expectation appeared to be justified by the very low alkalinity of 0.141×10^{-7} shown by the water at 10°.5 C., 54 miles W.S.W. of Golden Gate, San Francisco, on May 1, 1917.

No conclusions should be drawn from such meagre observations, but if future studies should demonstrate that low alkalinity is usually associated with easterly set of surface currents over the tropical oceans, the fact may become of importance to navigation owing to the ease and rapidity with which colorimetric tests of the alkalinity of sea water may be made by using a graded series of thymolsulphonephthalein tubes in the manner suggested by McClendon. In response to a request from Professor McClendon, tests were made of the carbon dioxide of the atmosphere at noon each day, but these showed that there is apparently no definite relation between the CO_2 tension of the air and the local alkalinity of the surface water.

The CO_2 tension was very variable and ranged from about 0.00045 to 0.00025 of an atmosphere, the average of 22 determinations being about 0.00035. There is also no definite relation between the salinity and the hydrogen-ion concentration of the ocean water, as will appear from the following tables.

The cold current which moves southward along the coast of California, is of low salinity being about 33.6 or 33.7 on an average whereas the salinity of the water between 1000 miles off the Californian coast and the Hawaiian Islands is about 35.

An elaborate study of the salinity and temperature of the water off the California coast has been made by George F. McEwen, *University of California Publications, Zoology*, **15**, 1916, (255–356, Plates 1–38), and the presence of an upwelling of cold water from the depths is clearly indicated along the California Coast as a result of studies by Michael and McEwen.

TABLE 1

TEMPERATURE AND ALKALINITY OF SEA WATER AT THE SURFACE FROM SAN FRANCISCO, CALIFORNIA, TO HONOLULU; AND THENCE TO PAGO PAGO, SAMOA, FEBRUARY 21 TO MARCH 5, 1917, ON S. S. *Sierra*, CAPTAIN JOHN J. K. KOUGHAN

DATE 1917	TEMPERATURE OF AIR °C.	TEMPERATURE OF SEA WATER, °C.	HYDROGEN-ION CONCENTRATION OF SEA WATER	PH OF SEA WATER	LATITUDE	LONGITUDE	MILES FROM PORT	BAROMETER IN INCHES	REMARKS
San Francisco to Honolulu									
February 21, noon	16°.6	12°.3	0.89×10^{-8}	8.05	36° 05′ N.	128° 38′ W.	302	29.79	Wind from west; rough sea
February 22, noon	15°.4	15°.4	0.676×10^{-8}	8.17	33° 32′ N.	135° 09′ W.	657	29.88	Rough; overcast. Wind from S–S. E.
February 23, noon	16°.5	17°.6	0.63×10^{-8}	8.2	30° 53′ N.	140° 53′ W.	988	29.53	Squally; rain, rough. Wind from W.N.W.
February 24, noon	18°.3	20°.1	0.589×10^{-8}	8.23	27° 49′ N.	146° 28′ W.	1334	30.01	Overcast, N.N.W. wind; moderate sea
February 25, noon	21°.2	21°.6	0.563×10^{-8}	8.25	24° 22′ N.	152° 19′ W.	1712	30.05	S.W. breeze; overcast, moderate sea
February 26, 10 a.m.	23°.4	23°.6	0.563×10^{-8}	8.25	21° 25′ N.	157° 25′ W.	2050		Clear; nearly calm; breeze from S.E., 30 miles off Honolulu
From Honolulu to Pago Pago, Samoa									
February 27, noon	24°.7	24°.2	0.563×10^{-8}	8.25	17° 52′ N.	159° 13′ W.	220	30.04	Clear, light trade wind from N.N.E.
February 28, noon	25°.5	25°.4	0.563×10^{-8}	8.25	12° 10′ N.	161° 17′ W.	588	29.97	Clear. Strong E.N.E. trade wind
March 1, noon	26°.3	26°.1	0.589×10^{-8}	8.23	6° 35′ N.	163° 21′ W.	940	29.84	Clear; rough; wind from E.N.E.
March 1, 5:20 p.m.	26°.2	25°.9	0.63×10^{-8}	8.2	5° 13′ N.	163° 40′ W.	1021		Strong current to east. Wind from N.E.
March 2, noon	24°.7	24°.2	0.676×10^{-8}	8.17	1° 07′ N.	165° 30′ W.	1293	29.78	Current to the N.W. all day; fair E. breeze; smooth.
March 2, 4.45 p.m.	24°.5	24°.85	0.656×10^{-8}	8.18	Equator	165° 50′ W.	1364		Current to the N.W. all day; fair E. breeze; smooth.
March 3, noon	26°.3	26°.4	0.63×10^{-8}	8.2	4° 35′ S.	167° 24′ W.	1653	29.79	Light breeze from east; clear
March 3, 5 p.m.	26°.4	26°.8	0.595×10^{-8}	8.225	5° 49′ S.	167° 45′ W.	1728		Light breeze from east; clear
March 4, noon	27°.4	28°.0	0.563×10^{-8}	8.25	10° 14′ S.	169° 14′ W.	2010	29.81	Clear, light breeze from east
March 4, 5 p.m.	27°.4	27°.9	0.563×10^{-8}	8.25	11° 29′ S.	169° 36′ W.	2085		Clear, light breeze from east
March 5, 6 a.m.	26°.8	27°.3	0.563×10^{-8}	8.25	14° 09′ S.	170° 31′ W.	2262		About 10 miles N. of Tutuila, Samoa

TABLE 2

TEMPERATURE, ALKALINITY, AND SALINITY OF SEA WATER AT THE SURFACE FROM PAGO PAGO, SAMOA, TO HONOLULU AND THENCE TO SAN FRANCISCO, CALIFORNIA, APRIL 19 TO MAY 1, 1917, ON S.S. *Ventura*, CAPTAIN J. H. DAWSON

DATE, 1917	TEMPERATURE OF AIR, ° C.	TEMPERATURE OF SEA, ° C.	HYDROGEN-ION CONCENTRATION OF SEA WATER	PH OF SEA WATER	SALINITY OF SEA WATER	LATITUDE	LONGITUDE	MILES FROM NEAREST PORT	BAROMETER	DIRECTION OF CURRENT	WEATHER
Pago Pago, Samoa, to Honolulu, Hawaiian Islands											
April 19, noon	25°.4	27°.8	0.575×10^{-8}	8.24	35.10	10° 15′ S.	169° 03′ W.	262	29.87		Light breeze from N.E.; showers. Raining when sample was taken
April 20, noon	26°.95	26°.75	0.708×10^{-8}	8.15	35.41	5° 10′ S.	167° 00′ W.	591	29.84	To the east	N.E. breeze; clear weather
April 21, noon	25°.4	24°.95	0.759×10^{-8}	8.12	35.26	Equator	165° 05′ W.	919	29.80	Strong current to the east	E.N.E. breeze; clear weather
April 22, noon	26°.4	25°.9	0.795×10^{-8}	8.1	35.05	5° 42′ N.	163° 12′ W.	1281	29.82	No current	Strong breeze from N.E.; moderate sea
April 23, noon	25°.4	25°.35	0.603×10^{-8}	8.22	34.58	11° 19′ N.	161° 05′ W.	1641	29.90	No current	Moderate breeze from N.E.; clear
April 23, 5.00 p.m.	25°.3	25°.5	0.588×10^{-8}	8.23		12° 29′ N.	160° 39′ W.	1723		No current	Moderate breeze from N.E.; clear
April 24, 7.30 a.m.	24°.7	24°.55	0.588×10^{-8}	8.23+		15° 58′ N.	159° 46′ W.	1932		Set to the west	Breeze from N.E.; clear; moderate sea
April 24, noon	24°.2	24°.5	0.617×10^{-8}	8.21	34.58	17° 03′ N′.	159° 23′ W.	1999	29.96	To the east	Clear E.N.E. breeze; moderate current
April 24, 5.30 p.m.	23°.5	24°.05	0.582×10^{-8}	8.235		18° 33′ N.	159° 00′ W.	2081		Set to the west	Clear; breeze from the east
April 25, 5.00 a.m.	21°.1	23°.75	0.617×10^{-8}	8.21				15 miles S. of Honolulu		Set strongly to the east	Calm, clear all day

TABLE 2—*Continued*

DATE, 1917	TEMPERATURE OF AIR, ° C.	TEMPERATURE OF SEA, ° C.	HYDROGEN-ION CONCENTRATION OF SEA WATER	PH OF SEA WATER	SALINITY OF SEA WATER	LATITUDE	LONGITUDE	MILES FROM NEAREST PORT	BAROMETER	DIRECTION OF CURRENT	WEATHER
Honolulu to San Francisco, California											
April 25, 6 30 p.m.	22°.4	23°.9	0.63×10^{-8}	8.2	34.94	5 miles off the S.E. Point of Oahu			29.93	Easterly set; current moving N.E.?	Calm, clear all day
April 26, noon	22°.6	25°.6	0.582×10^{-8}	8.21	34.79	23° 51′ N.	153° 44′ W.	281	29.94	Easterly set; current moving N.E.?	Breeze from the east; clear smooth sea
April 27, noon	21°.9	21°.6	0.588×10^{-8}	8.23+	35.23	27° 18′ N.	147° 52′ W.	662	29.95	Current southerly	Breeze from the east; overcast; moderate sea
April 28, noon	19°.4	19°.8	0.63×10^{-8}	8.2	35.05	30° 29′ N.	141° 50′ W.	1033	30.02	No current	Breeze from the east; clear; moderate sea
April 29, noon	16°.6	16°.6	0.795×10^{-8}	8.1	33.89	33° 39′ N.	135° 34′ W.	1405	30.13	Northerly current	Clear, nearly calm
April 30, noon	16°.1	14°.3	0.795×10^{-8}	8.1	33.17	36° 00′ N.	128° 59′ W.	1760	30.15	No current	Overcast. No rain. Nearly calm. Water blue as in mid-Pacific
May 1, 7.00 a.m.	12°.7	10°.5	0.141×10^{-7}	7.85	33.33	54 miles off Golden Gate, San Francisco Harbor		2036		Southerly current	Calm; clear; slight breeze from the west. Water dark greenish-brown to olive.